DEVELOPMENT OF VARIABLE INTAKE SYSTEM FOR SPARK-IGNITION ENGINE

MUHAMMAD HAFIZUDDIN BIN SALIM

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

This project is to study about the development of variable intake manifold for spark-ignition engine. Variable intake manifold is one of the methods in optimizing the performance of an engine. Some of manufacture have great interest on this system such as Volkswagen and Volvo companies. Further research was held by those companies. Each of them has different in design in order to race in technology of engine optimizing. This experiment was conducted by using flow bench that test on the flow rate of the new design intake manifold that has been fabricated. The test is on the intake manifold that is used by the 1600cc engine. Two intake manifolds were tested in this experiment, the Proton Waja intake manifold and the custom intake manifold that has been fabricated. The result found that the length of runner does affect the flow rate that produced by the intake manifold. The long runner will give better flow rate on the earlier phase of engine speed while the shorter runner will give better flow rate on the top end of engine speed. That is the reason why the variable intake manifold is better intake manifold compared to the standard intake manifold because it can be switch for the suitable length of runner depends on the engine speed condition.

ABSTRAK

Projek ini merupakan kajian mengenai pembuatan “*Variable Intake Manifold*” untuk enjin yang mengunakan sistem penyalaan pencucuh. “*Variable Intake Manifold*” merupakan salah satu kaedah dalam mengoptimumkan prestasi enjin. Beberapa syarikat pembuatan sangat berminat ke atas teknologi ini seperti syarikat Volkswagen dan Volvo. Mereka banyak melanjutkan kajian terhadap teknologi ini. Setiap pembuatan yang dilakukan sering berbeza dari segi reka bentuk didalam perlumbaan teknologi mengoptimumkan enjin ini. Ekseperimen in dilakukan dengan menggunakan bangku aliran bagi mengetahui kadar aliran yang terhasil daripada “*intake manifold”* itu tadi. Ujian yang dilakukan adalah berdasarkan enjin berkapasiti 1600cc. Dua “*intake manifold*” yang di uji di dalam eksperimen ini iaitu bagi penggunaan Proton Waja dan juga “*intake manifold”* yang telah di buat. Hasilnya didapati bahawa panjang pelari sememangnya mempengaruhi kadar aliran yang dihasilkan oleh “*intake manifold*”. Pelari yang panjang akan memberikan kadar aliran yang lebih baik pada fasa awal kelajuan enjin manakala pelari yang pendek akan memberikan kadar aliran yang lebih baik di hujung fasa kelajuan enjin. Disebabkan itu “*Variable Intake Manifold*” lebih baik berbanding “*intake manifold*” biasa kerana ia boleh mengubah laluan aliran mengikut kesesuaian kelajuan enjin.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Intake system is one of the core systems in automotive engine system. It is the system that responsible for fuel and air to get into the block cylinder system to perform combustion phase. Improvement in air intake system is necessary in order to increase the performance of an engine. There are different process and component for an engine that using carburetor system compared to injection system. For an engine that using carburetor to mix air and fuel, it consist two components that is carburetor and intake manifold. Then, for an engine that using injection system, the system consists of fuel injector, intake manifold and throttle body. This project will only consider the injection type as the research topic. This project is utilizing the concept of the variable length intake manifold to develop a new design of intake manifold.

Variable intake system or so called variable length intake manifold (VLIM) is different with the old system of basic manifold. This system used to have two different path of air flow that will be used as combustion element in combustion chamber. The first path will have longer flow path than the second path. There will be controlled by a valve that will close one of the paths depending on it usage. The long path is used when the engine operates at low load or low rpm and the short path is used at the higher rpm and engine load.

Variable intake system invented is to optimize power and torque for the engine and performance and it always create better fuel consumption that make it more efficient than the basic intake system. This is because the variable intake is operating as a switch for an engine, it will switch only when the engine is need to be switch to used what path of manifold. The long path will increase of the flow speed for low rpm usage and the shorter path will create higher capacity of air that used at higher rpm as the fuel usage is increased. This system will affect the swirl pattern and also it pressurization. Swirl pattern is very useful in the combustion process. A good swirl pattern will help the process to achieve complete combustion than it also will help to minimize the engine knocking. Pressurization is occurs when the manifold has the narrow part that will create dynamic pressure as it speed increased. So it will perform most likely the supercharge system at low pressure.

1.2 PROBLEM STATEMENT

The existing manifold will cause less fuel efficiency. With the variable length of manifold will create better fuel efficiency and create more and torque and power. Besides that, new design of variable intake may create better fuel consumption and also performance of the system better than late design. Better swirl pattern will be achieved with right shape of manifold that will depend on the narrow shape and angle of the manifold.

1.3 OBJECTIVES

The main objectives for this project are to achieve the following;

1. To propose a new design of variable intake system.
2. To test the propose design in term of it performance and effect.

1.4 SCOPE OF PROJECT

The scopes to cover for this project are listed as follows;

1. Design and fabricate the variable intake manifold for four cylinder four stroke engine (1600cc).
2. The intake manifold design is solely for the purpose of laboratory testing.
3. Data analysis will be studying on the effect of the intake manifold length.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

In this chapter, discussion is more on development of a new design of intake that will effect on the flow efficiency majorly. The parameter that will involve on this study is flow capacity and swirl pattern that creates from the intake manifold. These parameters will determine the efficiency of the intake system that will contribute on the performance of an engine. For all the parameters that will be taking care of, the fuel consumption of the engine that using this manifold also will be determined by studying those effect.

Spark-ignition type of engine system will be used to be work on the manifold that will be designed. Thus, all basic principle of 4-stroke spark-ignition system that involved in internal combustion engine will be revealed.

Besides that, one of the journals will be studying is the performance and fuel consumption that considering of all those parameters by using manifold that have variables of length plenum instead of variables of at their runners length. This is because those two mechanisms have different in their principle of operation but does have similarity in principle of effect and its parameters.

2.1 INTERNAL COMBUSTION ENGINE PRINCIPLE OPERATION

2.1.1 SPARK IGNITION ENGINE

The spark-ignition engine is a system that operating the combustion process that initiated by a precisely time discharge of a spark across an electrode gap in the combustion chamber. The spark is igniting the air-fuel mixture may be either homogeneous (i.e., the fuel-air mixture ratio may be approximately uniform throughout the combustion chamber) or stratified (i.e., the fuel-air mixture ratio may be more fuel-air lean in some regions of the combustion chamber than in other portions). Most of all spark-ignition engine without considering the Direct Injection Stratified Charge (DISC) SI engine, the air flow rate is used to control the power output that depends on the volumetric efficiency of the flow. Besides that, in almost all operating condition the fuel-air ratio is approximately constant and stoichiometric. DISC SI engine's is differing because the performance is controlled by varying he fuel flow rate that makes the fuel-air ratio is in variable condition while the volumetric efficiency is approximately constant.

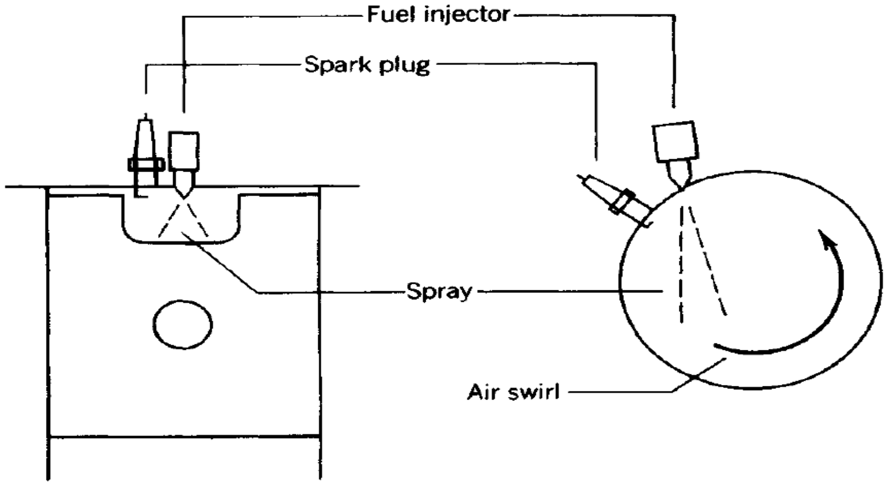

Figure 2.1: Schematic diagram of spark ignition engine

Source: (Matthews, 1990)

2.1.2 HOMOGENEOUS CHARGE SI ENGINE

Homogeneous charge SI engine had several phase from time to time. It is using method of inducting the fuel-air mixture during the intake process. Firstly, earlier invention that is by mixing fuel and air in the venturi section of a carburetor. Then, carburetor system is replaced by using throttle body fuel injection to give more precise control of the fuel-air mixture. As more precise control of the fuel-air mixture become more desirable, intake port fuel injection has almost entirely replaced throttle body injection system. This all process can be used in both of 4-stroke cycle or on a 2-stroke cycle.

2.1.3 BASICS OF 4-STROKE HOMOGENEOUS CHARGE SI ENGINE

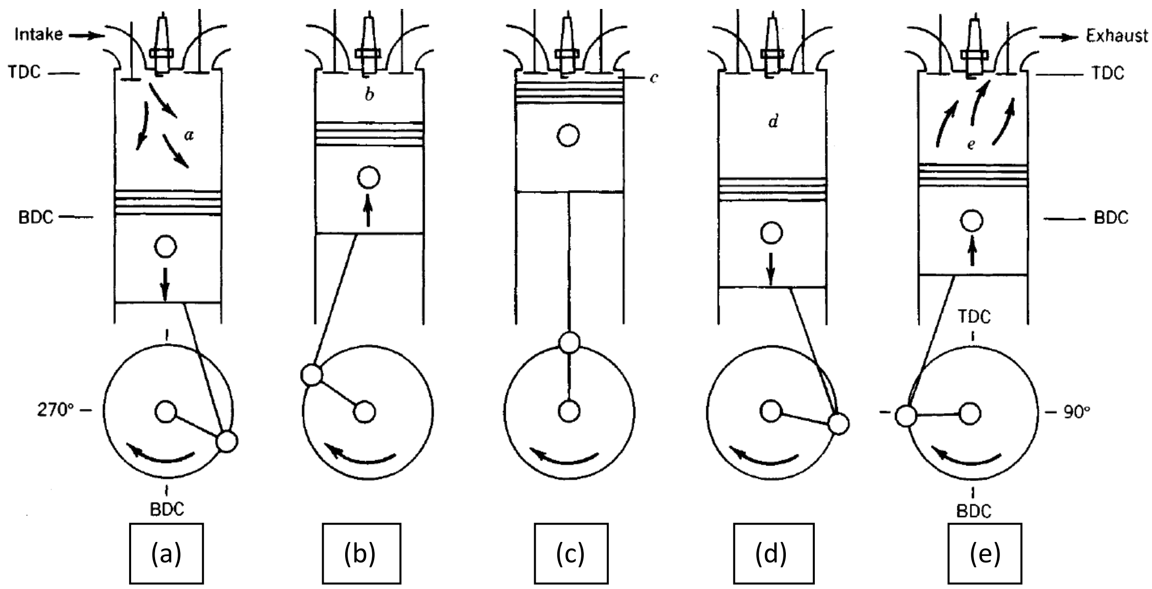

Figure 2.2: Four-Stroke Combustion Cycle

Source: (Matthews, 1990)

Today, 4-stroke system become more popular and also widely used in the automotive industry instead of 2-stroke system even though this 4-stroke system is more complicated but it produced better power efficiency and fuel consumption.

Base on Figure 2.2. During the first stroke(a), the piston move from top dead center (TDC – the closest gap between piston and cylinder head) where is at the minimum volume of combustion chamber to bottom dead center (BDC – the farthest gap between piston and the cylinder head) where is in the maximum volume of combustion chamber. As the piston travels down, the inlet valve is opened allowing the fuel-air mixture to be drawn into the combustion chamber. This stroke is called intake stroke.

The second stroke (b) is called compression stroke. During this process, both of the inlet and exhaust valve is closed. At this phase, the air-fuel mixture in the combustion chamber will be compress by movement of the piston back to the TDC. Just before the piston reaches the TDC a spark plug will ignite rapidly to combust the fuel air-mixture. The number of degrees before the top its stroke is the ignition advance. This process is to allow maximum pressure to occur slightly after TDC and producing torque.

The third stroke (d) is called power stroke where it consists of expansion process. It is during the movement to BDC after the second stroke gives power to producing torque.

Lastly, the fourth stroke (e) that called exhaust stroke. This is the process where the exhaust valve is opened to allow the products of combustion to be expelled by using movement of the piston from the BDC to the TDC. Then this process is being repeated afterward.

2.2 AIR INTAKE SYSTEM

Air intake system is widely used in internal combustion engine. This system is functional as the guider for the air that will be used in combustion chamber. Besides that, air intake system also functional as the filter for the air that will be used in the combustion process. The location of the air intake system always near to the engine especially the head cylinder part depends on the manufacturer. The components of the air intake system are including the air filter, intake manifold valve to cylinder and turbo with the intercooler for additional charge system. The air that needed for the combustion chamber will be increased as the engine is accelerates. That is why air intake system is optimized by manufacturer as the system will be used in the fuel consumption determination. The volumes of air that will be used were manipulated by a unit control system that was placed on the system.

As the second purpose of the system is to make sure the air that will enter into the combustion chamber is clean. A filter system is placed at the opening of the air intake system that will prevent incoming particles such as sand and dust. The standard requirement of a filter is to clean 99.8% volume of the incoming air (Nylander, 2008). Besides that, the filter also can function as the engine silencer for some product except for the performance type of filter. But the filter that silenced the noise of engine can reduce the performance of engine.

2.2.1 AIR INTAKE FILTER

Filter is one of the main components in the air intake system. This component is designed to remove moisture, dirt, dust, chaff and the like from the air before it reaches the engine. Effect of the flow restrictions in the air filter it increases the pressure ratio over the turbo which gives the same boost but to the cost of a higher working temperature. A low restriction intake system will be rewarded with more power and less heat (Bell, 1997). It must do this over a reasonable time period before servicing is required. The air cleaner also silences intake air noise. If dirt is allowed to enter the engine cylinders, the abrasive effects will result in rapid cylinder and piston ring wear. If the air cleaner is not serviced at appropriate intervals for the conditions in which it must operate, it will become restricted and prevent an adequate air supply for complete combustion from reaching the cylinders. Incomplete combustion results in carbon deposits on valves, rings, and pistons, which in turn cause engine wear and oil consumption problems. Air cleaner types include precleaners, dry types of various designs, and oil bath types. Air cleaner capacity (cubic feet per minute or litre per minute) may have to be up to twice as great on a turbocharged engine as compared with the same engine naturally aspirated.

2.2.2 TURBOCHARGING

Turbocharging system is one of the methods in enhancing the air intake system performance of an engine. It increasing the power output of an engine by introducing air into the engine cylinder with higher velocity and density compared to the natural aspirated engine that only depending on the ambient density. The system is using exhaust gas as the source of mechanical work that is used in order to generate the turbine of the system to perform suction of air from ambient to be drawn into the combustion chamber. That is why turbocharging plays a crucial role in utilizing exhaust gas energy efficiently (Kesgin, 2004). The operation of turbocharge is shown as Figure 2.3.

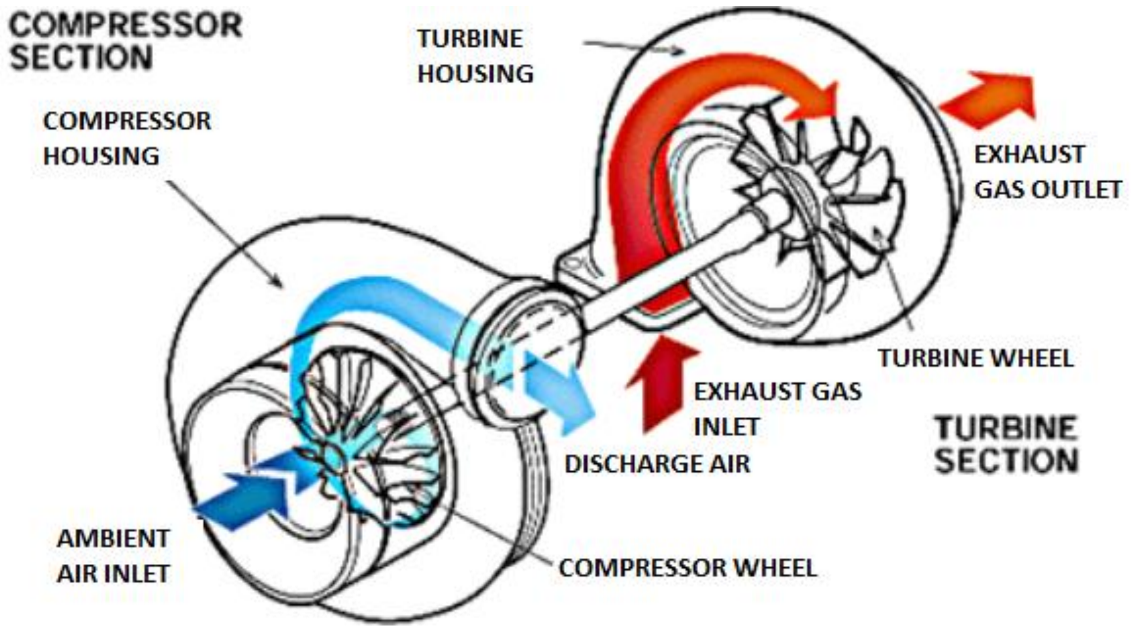

Figure 2.3: Turbocharging mechanism

Source: (Alsaeed, 2005)

In fact, increasing the power output of the engine (also called supercharging) does not always come with a better efficiency. There is a recognized practice to supercharge the automotive engine by using the mechanical power of the engine itself. In other words, a belt can transfer the engine torque to a compressor that boosts the pressure of the intake air going into the engine cylinder. Obviously that method would take from the engine power itself, while the supercharging is being performed. However, turbochargers can utilize the wasted hot exhaust gas to increase the engine power, without as much loss of efficiency (Alsaeed, 2005).

The commercially available turbochargers can be subdivided into two principal groups: those primarily designed for use on automotive and truck engines, and those for use on medium-speed and low speed diesel engines for railway traction, electricity-generating sets, industrial and marine applications. The difference between the two principal groups can be summed up as a contrast between small, simple and cheaply mass-produced units, and larger, more complex, expensive and reliable industrial or large marine units (Alsaeed, 2005).

2.2.3 INTAKE MANIFOLD

Intake manifold is the most important element in the air intake system. This is the main components that determine the value of flow that will be allowed to be used in the combustion chamber. The intake manifold is always works on with the throttle of the system that will use in air regulation. The manifold is always shape in piping as the function is to guide the air to be used into the combustion chamber. The air the passes through a section of piping, the length of this section of pipe is almost entirely dictated by geometric constraints around the engine (Porter, 2009). The theory of pressure waves is the common theory that will be used in the intake manifold construction. The focus of in designing the intake manifold is put on the plenum and runners of the intake manifold as this two components are the basic component of intake manifold. Figure 2.4 is showing the plenum and runners and position and also the flow of the air from the throttle body through the runners and plenum. Many researches were conducted on the plenum and runners in optimizing the intake manifold performance. The research is commonly studying about possible ways of increasing the volumetric efficiency of an engine. The approach studied has been to try to increase the kinetic energy of the air during the induction process thus achieving a "ram-charge" effect or supercharging effect in the cylinder (Shwallie, 1972).The intake manifold geometry has strong influence on the volumetric efficiency in IC engines (Winterbone and Pearson, 1999). One of the products of studying in the intake manifold field is the variable intake manifold or resonance intake manifold. The general idea is that for lower engine speed the length of the inlet pipe must be longer and as the speed increases the length should be shortened. That is exactly what systems of variable length intake manifold do in order to optimize power and torque across the range of engine speed operation, as well as to help provide better fuel efficiency(Varsos, 2010).

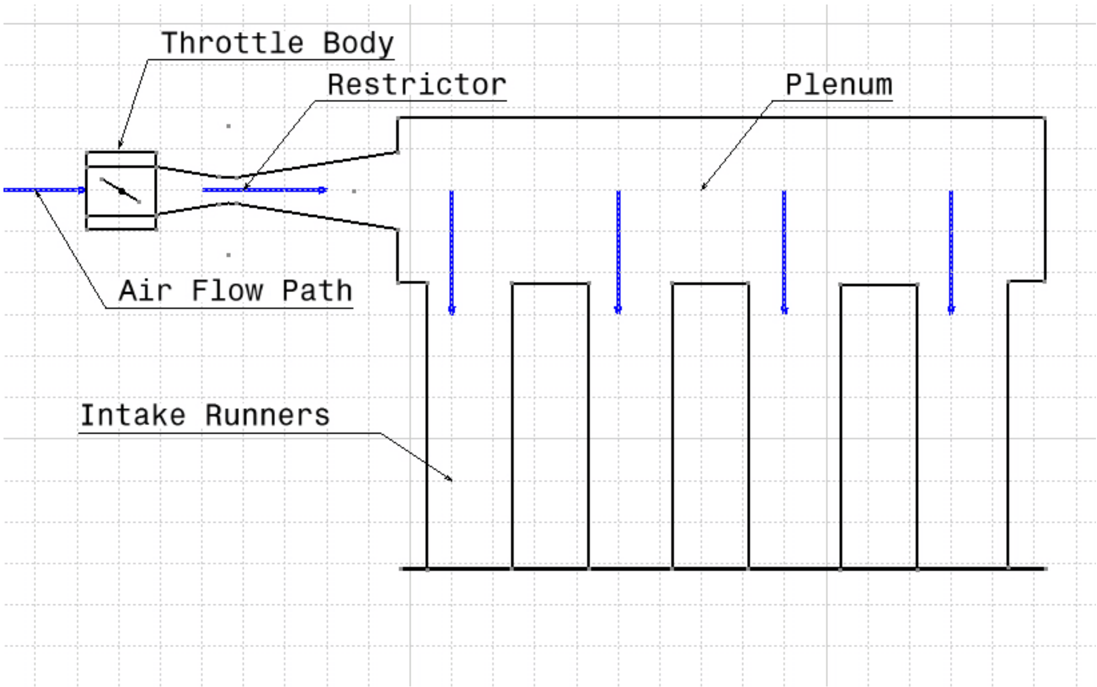

Figure 2.4: Basic intake manifold diagram.

Source: (Porter, 2009)

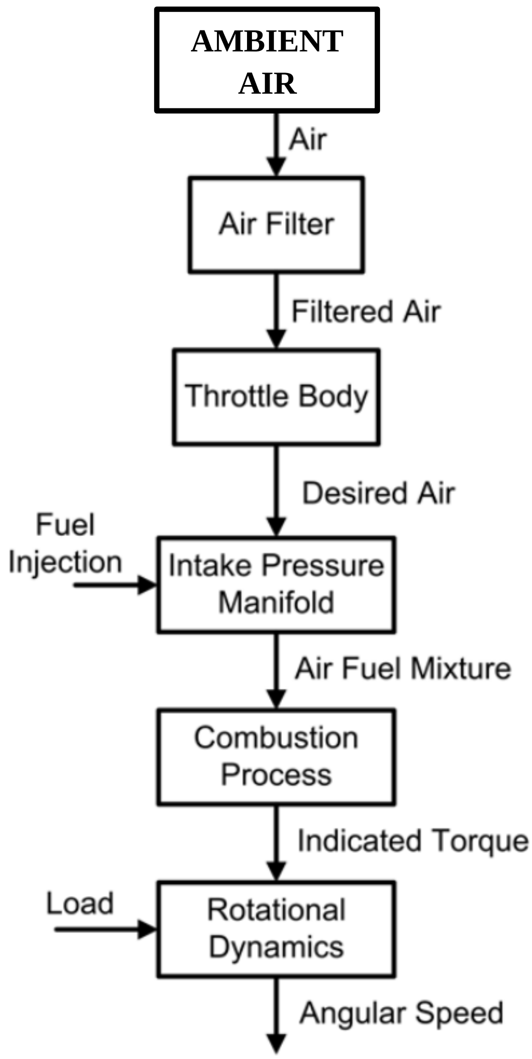

Figure 2.5: Component modeling flow

Source: (Ahmed, 2011)

2.2.4 VARIABLE INTAKE MANIFOLD

In order to get the good design of an intake manifold with variable length, the variable intake manifold from 3.2-liter V6 engine of Volkswagen is taken as the one of a reference. These intake manifold designs basically have two different path of air flow with using a valve that separating them. It consist of two port of air flow that one is called torque port and the other one is called performance port. This design used to optimize the usage of intake system. It will increase low rpm torque and high rpm power by taking advantage of the self-charging or “ram effect “that exist at some engine speed. This effect produced by tuning the intake manifold air duct length. At the higher rpm, short and larger diameter of air flow will be drawn in to the combustion chamber by using the performance port.

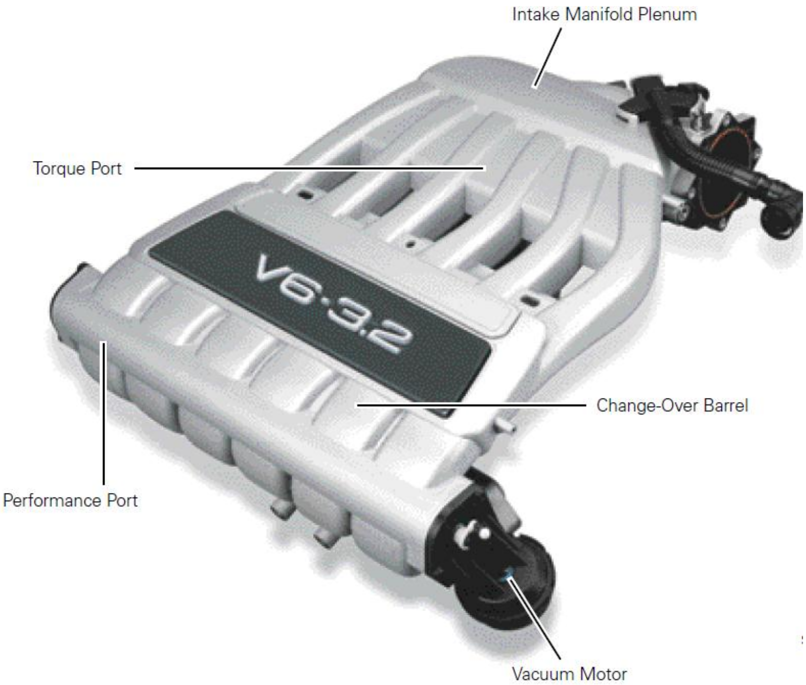

Figure 2.6: Volkswagen variable intake manifold

Source: (Volkswagen of America, 2006)

2.2.5 PRINCIPLES OF VARIABLE RESONANCE INTAKE MANIFOLD OPERATION

Combustion process that operates in the cylinder created pressure different between the cylinder combustion chamber and the intake manifold. The intake valves opening will create some sort of wave form in the intake manifold that moves from intake valve ports toward the torque at the speed of sound. Figure 2.7 as reference.

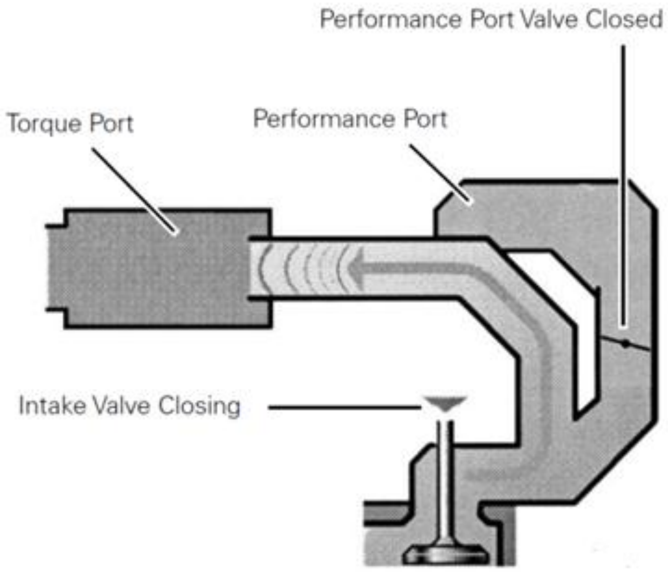

Figure 2.7: Intake manifold diagram for operation 1

Source: (Volkswagen of America,2006)

After that, opening the end of the intake duct at the torque port will rapidly form a intake wave same effect as a solid wall has on a ball. It will cause the wave to reflect back toward the intake valve ports in the form of a high pressure wave. Figure 2.8 as reference.

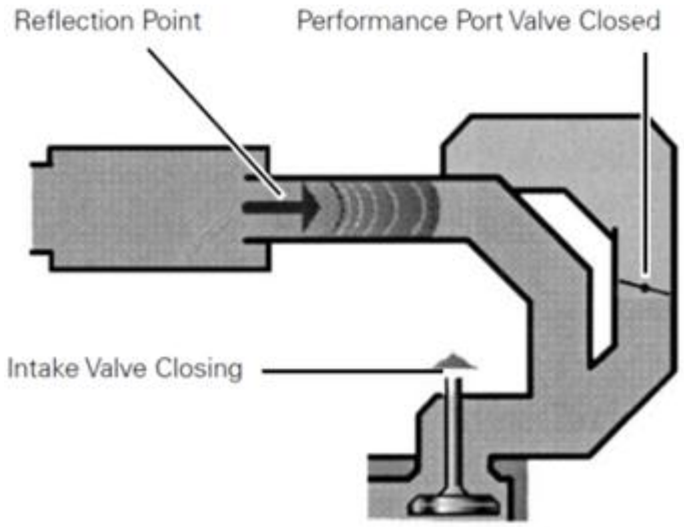

Figure 2.8: Intake manifold diagram for operation 2

Source: (Volkswagen of America,2006)

As the engine in still in low rpm, the source of the air flow is still from the torque ports. This is the phase where the wave forms the maximum pressure behind the valve waiting to enter the combustion chamber. At this time, the piston is in top dead center position. After the late fuel-air mixture is entering the combustion chamber, the new wave form that consists of maximum charging will be form rapidly as it called self-charging or "ram effect." Figure 2.9 as reference.

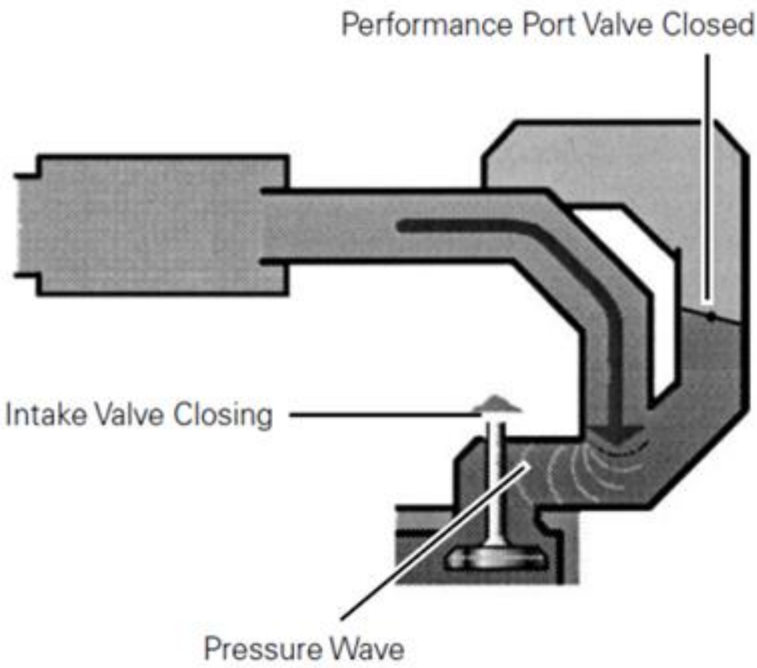

Figure 2.9: Intake manifold diagram for operation 3

Source: (Volkswagen of America,2006)

When the speed of the engine increase, there are certain phase that make the high pressure will have less time to reach the inlet port. It is because the wave is limits to only at speed of sound. There is where the shorter intake must be taking place to solve the problem. Figure 2.10 as reference.